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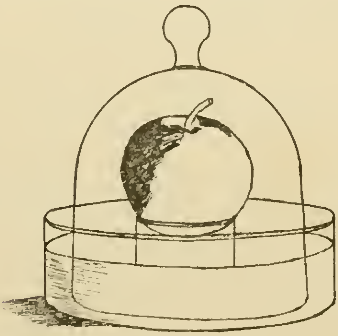
The Respiration of Apples and its Relation to Their Keeping



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AGRICULTURE AND THE MECHANIC ARTS
DURHAM, N. H.

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THE RESPIRATION OF APPLES AND ITS RELATION TO THEIR KEEPING.

BY FRED W. MORSE.

The respiration of animals is a well known action and the necessity for it in the living creature is fully appreciated. The fact that plants and parts of plants must also breathe is not so commonly understood. Yet all living cells, whether a part of animal matter or vegetable matter, must have oxygen to keep them alive and they give up carbon dioxide and water as a result of the action of the oxygen on some of their contents. Parts of plants when cut off from the main stem do not die at once, and must continue to breathe. This is true, whether the severed part is a leafy branch, a fruit or a root; but some parts live much longer after removal than others, and the apple continues to breathe for many weeks after it has been picked from the tree.

The chief products of respiration are the same in plants as in animals, namely carbon dioxide (commonly called carbonic acid), and water. These products can be easily shown by placing one or more apples in a glass jar and covering it tightly. In a few hours a dewy film will cover the inner surface of the jar, that in time will collect into drops which will trickle to the bottom. On opening the jar, a little clear lime water may be poured into it without touching the fruit, and the lime water will be seen to turn milky, just as it will if an animal's breath is forced through it.

The taking up of oxygen from the air can also be readily shown by the following interesting experiment.

In a large basin partially filled with water set a small support on which is placed an apple and a small open dish containing a solution of caustic soda or potash. The apple should not touch the water nor the caustic solution. Cover the support and its contents by a large bell glass or wide jar with its mouth wholly in the water. Now as the apple breathes in the oxygen of the air, and breathes out carbonic acid, the latter will be absorbed by the caustic solution while water will rise in the jar to fill the space made vacant by the removal of the oxygen. Finally the water will fill about one fifth of the air space originally present and remain stationary because the oxygen is all used.

Respiration, whether in animals or in plants, causes a

destruction of matter in the cells much like the destruction of wood in a stove, and the rate at which this destruction goes on can be measured by determining the amount of carbonic acid that is breathed out in a given length of time.

In animals, under usual conditions, the food which they eat makes good the losses produced by respiration. An animal, however, may live without food for some time, during which period it still breathes in oxygen and breathes out carbonic acid and water, but it steadily loses weight and grows thin in flesh because there is a steady destruction of cell material with no food to replace it.

Fruit, after having been picked from the tree, is in the condition of the starving animal. Its cells still keep up respiration with nothing in the way of food to make good the losses produced by the action. Since apples and other fruits have no body heat to maintain, the breathing process is not so active as in animals, and they may last months after being picked from the tree. Yet there is a steady, continuous loss in weight as the weeks go by, although the fruit is sound and firm.

For example, fruit put in cold storage Nov. 13 and weighed at intervals of two months had lost as follows:

January 2,	0.33 per cent.	March 5,	2.34 per cent.
May 6,	3.60 per cent.	July 1,	4.71 per cent.

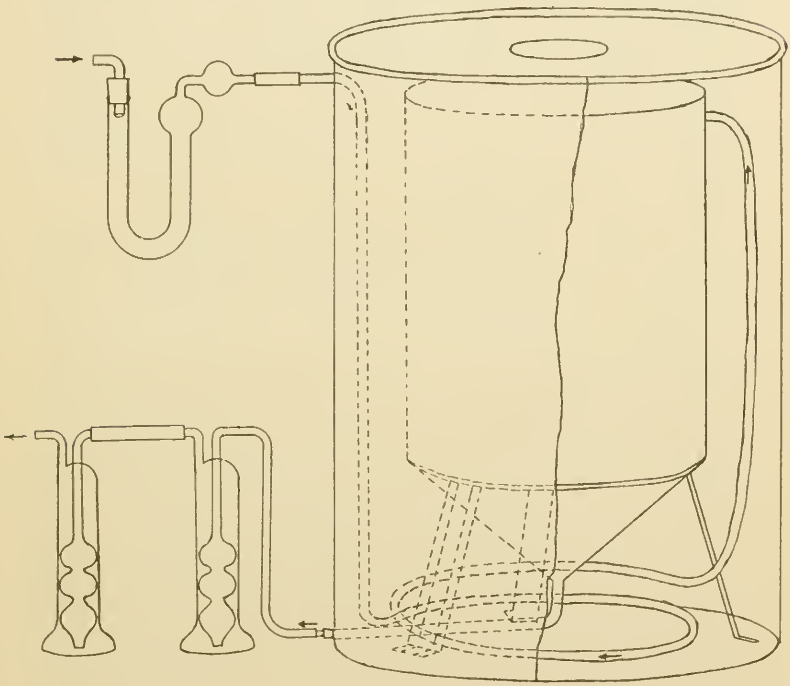
That the shrinkage in weight is due to respiration and not to simple drying out of the water is shown by the practically constant percentages of water and dry matter, since if the solid material was not destroyed it should gradually increase in proportion while the water would decrease. Results proving this point are here given.

A lot of Baldwin apples were set aside in October and a few of them analyzed at intervals.

October 24,	water, 85.45;	dry matter, 14.55.
October 31,	water, 85.41;	dry matter, 14.59.
November 21,	water, 85.23;	dry matter, 14.77.
November 29,	water, 85.02;	dry matter, 14.98.
December 27,	water, 85.56;	dry matter, 14.44.
April 20,	water, 86.19;	dry matter, 13.81.

Respiration is partly a chemical reaction and in apples, like most chemical reactions in the laboratory, it grows more rapid as the fruit becomes warmer, and is slowed down when the fruit is cooled. If two sets of experiments were carried out as described in a previous paragraph, one set in a refrigerator, and the other in a warm room, it would be easily seen at the end of four or five days that the warm room had caused the larger amount of respiration.

Since no exact figures had been obtained showing just how rapidly an apple was changed in composition when stored at an ice cold temperature compared with another apple at 45 degrees and another at summer temperature, it seemed possible to measure the rate by determining the amount of carbonic acid given off by the fruit at different temperatures. The carbonic acid would not show the kind of changes taking place within the cells of the apple; but it



would be a measure of the rate at which those changes were progressing since the formation of the carbonic acid must be one of the reactions concerned in them.

A simple apparatus was planned, by which the carbonic acid breathed out of the apples could be collected and measured. The apparatus consisted of a cylindrical copper vessel supported on three legs, and large enough to hold about six quarts. The top of the vessel or can was closed by a circular plate of glass, that rested on a narrow shelf of copper soldered around the inside of the cylinder a little below the top. An inlet tube was soldered into the vessel

just below the glass cover, and an outlet tube was fixed in the bottom of the vessel which was shaped like a funnel, so that the gas would all collect around the outlet, since carbonic acid is heavier than air. Air could be drawn into the copper can through the inlet tube after first passing through a bent glass tube containing a solution of caustic potash, which removed any carbonic acid which was in the air. It would then pass out through the outlet tube which was connected with some glass bulbs containing caustic solutions to collect all carbonic acid passing out of the can.

The current of air through the apparatus was maintained by connecting the absorption glass by means of rubber tubing with a large jar of water, from which a small stream was allowed to trickle at a rate that would keep the air steadily bubbling through the potash solutions connected with the inlet and outlet tubes.

The copper vessel stood inside a galvanized iron tank which could be filled with water or ice when low temperatures were desired. The temperatures at which most of the experiments were carried on were 32° Fahrenheit, or that of modern cold storage rooms, 40° to 50° corresponding to cool cellars and 68° to 80°, or room temperatures equivalent to early fall.

At the beginning of an experiment about two kilograms (four to five pounds) of perfectly sound Baldwin apples were placed in the copper chamber and the glass cover was firmly sealed in place with putty. The current of air was started through the apparatus and made to continue until it was considered time to determine the amount of carbonic acid which had been collected. The length of time which had passed since starting the current was noted down and the circulation was then stopped by shutting off the stream of water. The potash solutions were next analyzed for carbonic acid and finally the apples were removed from the can until another experiment was begun.

The length of time during which the carbonic acid was collected ranged from 5 hours to 48 hours of continuous circulation. In the earliest experiments it was found inconvenient to keep up the circulation of air outside of laboratory hours, and the runs were therefore made short in order to make the necessary determinations of carbonic acid at the end. Later, it was made possible to keep up a continuous circulation over night and several long periods of 24 to 48 hours were conducted at the different temperatures.

In order to have a common basis for comparing one experiment with another, the results were all recalculated for one kilogram of fruit and one hour of time in milligrams of carbonic acid. There were two different seasons in which the experiments were carried on. In the first season, temperatures above that of melting ice were not closely regulated but were allowed to vary several degrees as in ordinary practice. In the second season the temperatures were held closely at the points selected for comparison and the runs were of equal lengths of time.

The results of the first season are given in separate tables below.

Carbonic acid exhaled by 1 kilogram of apples in 1 hour at summer temperatures, 65° to 77° Fahrenheit:

October	16,	8½ hours,	16.4 milligrams.
October	17,	8 hours,	18.7 milligrams.
November	5,	6¼ hours,	12.6 milligrams.
November	6,	6½ hours,	12.6 milligrams.
November	12,	6¼ hours,	18.2 milligrams.
December	9,	5 hours,	18.0 milligrams.
December	10,	6 hours,	17.9 milligrams.
December	11,	6½ hours,	23.0 milligrams.
December	12,	6½ hours,	26.7 milligrams.
February	26–28,	47 hours,	17.9 milligrams.

The average rate of exhalation of carbonic acid at summer temperature was 18. milligrams per hour for one kilogram of fruit.

Carbonic acid exhaled by 1 kilogram of apples in 1 hour at cellar temperatures, 40° to 50° Fahrenheit:

October	22,	5 hours,	8.0 milligrams.
November	7,	6 hours,	7.3 milligrams.
December	2,	5½ hours,	8.7 milligrams.
December	3,	6½ hours,	9.5 milligrams.
December	4,	6 hours,	8.8 milligrams.
December	5,	7½ hours,	7.9 milligrams.
December	6,	5½ hours,	9.6 milligrams.
March	16–18,	48 hours,	5.5 milligrams.

The average rate of exhalation of carbonic acid at cellar temperature was 8.1 milligrams per hour for one kilogram of fruit.

Carbonic acid exhaled by 1 kilogram of apples in 1 hour at temperature of melting ice, 32° Fahrenheit:

October	29,	22 hours,	2.3 milligrams.
October	30,	6⅓ hours,	2.6 milligrams.
November	8,	8 hours,	3.8 milligrams.
March	2-4,	46½ hours,	2.4 milligrams.
March	4–7,	55¾ hours,	2.8 milligrams.
March	9–11,	48 hours,	2.2 milligrams.

The average rate of exhalation of carbonic acid at the temperature of melting ice was 2.7 milligrams per hour for one kilogram of fruit.

The results of the second season are given in the same form as for the first.

Carbonic acid exhaled by 1 kilogram of apples for 1 hour at different temperatures:

50° Fahrenheit.	
March 15, 6 hours,	13 6 milligrams.
March 16, 6 hours,	13.6 milligrams.
March 18, 6 hours,	12.5 milligrams.
32° Fahrenheit.	
March 21, 6 hours,	5.7 milligrams.
March 22, 6 hours,	5.3 milligrams.
March 23, 6 hours,	4.0 milligrams.
March 24, 6 hours,	5.3 milligrams.
68° Fahrenheit.	
March 25, 6 hours,	21.9 milligrams.
March 28, 6 hours,	21.2 milligrams.
March 31, 6 hours,	22.5 milligrams.

The average rate of exhalation of carbonic acid for one kilogram of apples per hour was 13.2 milligrams at 50 degrees, 5.2 milligrams at 32 degrees and 21.9 milligrams at 68 degrees.

It will be seen on comparing the average rates of exhalation of carbonic acid at the different temperatures, that in passing from melting ice (32°) to cellar temperatures (45° to 50°) the rate nearly triples, and in passing from the medium temperature to summer temperatures the rate doubles.

Since the breathing out of carbonic acid is an indication of the rate of chemical change within the fruit, it follows that changes of composition must take place from four to six times as fast at summer temperatures as in cold storage and from two to three times as fast in cool cellars as in cold storage.

These increases in rate are in agreement with the laws of chemical action, as the speed of such reactions is found to double and sometimes to triple when the temperature is raised 18 degrees Fahrenheit (10 degrees Centigrade).

There is a practical application of this law to be made to the care of fruit, especially at apple picking time.

It is frequently the case that warm days with temperatures of 70 degrees occur in October and sometimes continue for a considerable period. Fancy apples intended for long keeping in cold storage should be cooled as soon as possible and kept cold. The breathing process is at the expense of cell contents and must weaken the keeping qualities as it goes on. And this destructive action is from four to six times as fast out of cold storage as inside it.

Another fact in connection with the respiration is important. It is not stopped in cold storage, but simply slowed. Apples cannot be kept indefinitely but keep about twice as long in cold storage as in a cool cellar.

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